STATE OF CALIFORNIA — ENVIRONMENTAL PROTECTION AGENCY

DEPARTMENT OF TOXIC SUBSTANCES CONTROL

REGION 2
[redacted] HEINZ AVE., SUITE 200
[redacted]RKELEY, CA 94710-2737

February 8, 1996

Engineering Field Activity, West
Attn Mr. David Song, Code 1832.3
900 Commodore Drive
San Bruno, California 94066-5006

RESPONSE TO AGENCIES COMMENTS ON RESULTS OF SUBSURFACE RADIATION INVESTIGATION ON PARCELS B AND E, HUNTERS POINT ANNEX

Dear Mr. Song:

The Department of Toxic Substances Control is forwarding the enclosed comments from the Department of Health Services.

Should you have any questions regarding this letter, please call me at (510) 540-3821.

Sincerely,

Cyrus Shabahari
Project Manager
Office of Military facilities

Enclosure

cc: US EPA, Region IX
Attn: Claire Trombadore [H-9-2]
75 Hawthorne Street
San Francisco, California 94105

Regional water Quality Control Board
Attn: Richard Hiett
2101 Webster Street, Suite 500
Oakland, California 94612

State of California Department of Health Services

Memorandum

: January 23, 1996

To : Cyrus Shabahari
Department of Toxic Substances Control (DTSC), Region 2
Office of Military Facilities
700 Heinz Avenue, Suite 200
Berkeley, California 94710

From : Environmental Management Branch
601 North 7th Street (MS 396)
(916) 445-0498

Subject : Department of Health Services' (DHS) review of the U.S. Navy's response to DHS' June 14, 1995 comments on "Results of Subsurface Radiation Investigation in Parcels B and E.

Enclosed are DHS' comments on the subject document. In general, these responses were not responsive to the depth of the comments. If unrestricted release of the parcel is the goal, the enclosed review may be used to assure that future reports are responsive to DHS' concerns.

This review was performed by Ms. Deirdre Dement, Associate Health Physicist, in support of the Interagency Agreement between DHS and DTSC. If you need additional information, please contact me at (916) 324-2209, or Ms. Dement at (916) 324-1378.

Darice G. Bailey
Senior Health Physicist

Attachment

cc: Mr. Donn Diebert
Office of Military Facilities
Department of Toxic Substances Control, Region 1
10151 Croydon Way, Suite 3
Sacramento, CA 95827

cc: Mr. John Adams
Division of Clean Water Programs
State Water Resources Control Board
2014 T Street, Suite 130
Sacramento, CA 94244-2120

Ms. Deirdre Dement
Environmental Management Branch
601 North 7th Street, MS 396
P.O. Box 942732
Sacramento, CA 94234-7320

Department of Health Services

Document: Review of Navy's Response to DHS Review of Draft Report Titled "Results of Subsurface Radiation Investigation in Parcels B and E", March 27, 1995

Facility: Hunter's Point Annex, San Francisco, CA

General Comments

The following comments are in response to the request from and subsequent telephone conversations with Mr. Cyrus Shabahari of Department of Toxic Substances Control to review the Navy's response to the DHS review of a draft report of a subsurface radiation investigation of Parcels B and E at Hunter's Point Annex. DHS submitted the original review comments on June 14, 1995 and received the Navy's response on January 12, 1996.

Since there is no data presented in the reviewed report that would meet the criteria for release of land for unrestricted use, DHS will not make an assessment based on this report. When evaluating the release of property that has undergone remediation because of the presence of radioactive materials, DHS will use the enclosed DHS document "Guidance for Cleanup of Radioactivity on Closing Military Bases for Unrestricted Public Use of Property." In addition, DHS will use for reference US Nuclear Regulatory Commission regulatory guides on decommissioning (NUREG/CR-5849, NUREG-1500, NUREG-1505, and NUREG-1506).

April 5, 1994

GUIDANCE FOR CLEANUP OF RADIOACTIVITY ON CLOSING MILITARY BASES FOR UNRESTRICTED PUBLIC USE OF PROPERTY

Environmental Management Branch
Division of Drinking Water and Environmental Management

Radiological Health Branch
Division of Food, Drug and Radiation Safety

California Department of Health Services
601 North 7th Street
P.O. Box 942732
Sacramento, CA 94234-7320

1. INTRODUCTION

1.1. This document presents guidance to assist interested parties in the evaluation of levels of environmental radioactivity on closing military bases and resulting radiation exposures to the general population. It provides direction on managing potential risks of cancer from radionuclides in the environment for purposes of site cleanup and decontamination associated with the cleanup of closing military bases so that the property can be utilized by the public. Reducing radiation exposure levels and minimizing cancer risks to the levels set forth in this discussion will be protective against other adverse health effects of radiation (*e.g.*, reproductive and developmental effects) that would be associated with environmental radioactive contamination.

1.2 The Department of Health Services (DHS) views it appropriate to maintain consistency with existing health-based standards whenever those standards exist. Hence, DHS believes that its drinking water standards for radionuclides are appropriate cleanup levels for water, as are the radon action level for indoor air, and the federal Environmental Protection Agency's (EPA's) standards for cleanup of residual radium in soil.

2. CLEANUP OF RADIOACTIVE SITES—BASIC PRINCIPLES

2.1. Documentation of the history of use, storage and disposal of radioactive material on the site should be complete.

2.1.1. A site characterization document for the site should identify all past and current use, storage and disposal of radioactive material.

2.1.1.1. The site characterization for radioactive material should begin with a review of the general and specific licenses from the US Nuclear Regulatory Commission (US NRC) and Department of Defense (DOD) permits for radioactive material on the site, and reports required pursuant to those licenses and permits.

2.1.1.2. The site characterization should include reviews of written histories and documents, and oral histories or interviews with current and past employees—including current and past base radiation safety officers—and others who would have historical insights into past activities using radioactive material.

2.1.1.3. The various military service branches within DOD have organizations that need to be contacted for consultation about characterization of the site, and for documentation of the historic use, storage, and disposal of radioactive material at the base in question. These include:

- The Air Force's Radioisotope Committee and Armstrong Laboratory at Brooks Air Force Base in Texas.
- The Army's Environmental Hygiene Agency at the Aberdeen Proving Ground, Maryland.
- The Army Corps of Engineers in Omaha, Nebraska.
- The Navy's Radiological Affairs Support Office in Yorktown, Virginia.

2.2. Cleanup of discrete radioactive items.

2.2.1. With the exception of standard commercial smoke detectors installed in buildings, all discrete items that are radioactive and known to be present should be removed. This includes, but is not limited to, (a) radioactive sources, (b) gauges, dials, knobs and other material painted with or containing radium or other radionuclides, (c) radionuclides in electronic equipment and instrumentation, and (d) materials containing depleted uranium. Examples of sources of radioactivity on military bases are presented in Table 2-1.

2.2.2. If radioactive items cannot be removed, unrestricted public use would not be an option for the property in question. The nature of restrictions to be placed on the property, as well as the future use of the site, would require deliberations by concerned parties.

2.3. Cleanup of diffuse radioactive contamination.

2.3.1. Radioactive contamination on the property that is diffuse should be removed to levels that would minimize the cancer risk to the exposed population, consistent with the guidance that follows in this document.

2.3.2. If diffuse radioactive contamination cannot be removed to levels that would minimize the cancer risk to the exposed population, unrestricted public use would not be an option for the property in question.

Table 2-1. Examples of sources of radioactivity on military bases.

The Department of the Army's Corps of Engineers distributed to its regional commands a memorandum (dated December 8, 1993) addressing awareness of radioactive materials used at DOD facilities. That memorandum pointed out that the DOD has issued over 2800 different types of instruments and articles containing radioactive materials, and that radioactive contamination may exist in materials in base supply warehouses, or in shops used for the manufacture, repair or maintenance of such articles. The memorandum also points out that "during the 1940s, 1950s, and 1960s, on-base burial, sometimes in radioactive waste disposal cells and often in on-base landfills, was a reasonable and acceptable disposal technique." That memo plus other information from DOD point out a number of sources of radioactivity that may be found on military bases:

a. Radium dials, gauges, and illuminators were used extensively in military applications, and represent the most common and the greatest radioactive health and environmental hazard found on bases. Examples include luminous dials on a variety of components used in navigation and communication, and on watch dials, weapons sights, and compasses. To illustrate this point, about half a million deck markers (each with about 20 microcuries of radium-226 or strontium-90) were made for and used by the Navy in 1952. The decommissioning of the Battleships Iowa, Missouri, and New Jersey resulted in the removal of about 1,200 radium-226 components from each vessel. As another example, the equipment utilized for mobile ground control approach (GCA) radar systems contained extensive amounts of radium-226 in readily accessible components such as knobs, dials, and gauges. Some of this GCA equipment had a component that contained up to 5,000 microcuries of radium-226.

b. Depleted uranium used in armor and armor piercing ordnance, as well as in shipping containers for use in sealed source radiography.

c. Tritium as a source of illumination, especially for exit signs.

d. Thorium as a component in lenses to enhance the optical quality, and in magnesium-thorium metal used for machinery, aircraft and rocket parts, plus welding rods used in thick metal welding.

e. Hospital and research facilities used tritium and carbon-14 in liquid scintillation counting. Liquid scintillation counting fluids contain xylene or toluene which are hazardous wastes.

f. Washdown areas for contaminated equipment (*e.g.*, aircraft and ships) used in association with or in monitoring above-ground nuclear weapons tests.

g. Calibration sources for radiation survey instruments.

h. Hospital sources used in diagnostic techniques and for radiation therapy procedures, plus sources used in research facilities.

i. Sources used in radiography.

j. Gauges used to measure the level, thickness, or the density of an object of interest.

k. Sources known as commodities which are used extensively as components for weapons systems and within navigation and communication equipment.

l. Low-level radioactive waste from reactor and primary plant maintenance and repair, weapons processing, and associated with some of the sources mentioned above.

3. CHEMICAL CARCINOGEN EXPOSURES—REGULATORY PERSPECTIVE

3.1. Carcinogenic chemical substances that are released into the environment are regulated for the protection of public health to strict standards in non-occupational settings. Regulatory levels are established to limit the cancer risk. Cancer risk is expressed in terms of "excess" cancer cases, that is, those that exceed the cancer cases that would normally occur in a given population (i.e., about 25 to 30%).

3.1.1. The lower end of the range (one excess case of cancer in a population of 1,000,000 people exposed for a 70-year lifetime, the so-called "10^{-6}" risk) is the usual regulatory goal, though costs and technical feasibility may lead to the higher end of the range (one excess case of cancer in an exposed population of 10,000 people exposed for a 70-year lifetime (the "10^{-4}" risk).

3.1.1.1. Human exposures to chemical carcinogens that would result in lifetime cancer risks below the 10^{-6} risk are often referred to as posing a *"de minimis"* risk, and are usually do not receive much regulatory attention, although public health agencies often seek to reduce exposures that result in risks of this magnitude, as well.

3.1.1.2. Human exposures to chemical carcinogens that would result in lifetime cancer risks greater than one excess case of cancer in an population of 100,000 people (the 10^{-5} risk), if allowed by regulatory agencies, could be required to be accompanied by warnings or notices to the exposed population. For example, see California Health and Safety Code §25249.5, *et seq.* or §44300, *et seq.*

3.1.1.3. Risks of 10^{-4} may be allowed by federal and state regulatory agencies if there is an offsetting public health benefit (*e.g.*, the cancer risk from exposure to byproducts of drinking water chlorination), or if the costs of cleanup to a lower risk level are considered excessive, when compared to the benefit.

3.1.1.4. Human exposures to chemical carcinogens that would result in cancer risks to the general population (non-occupational exposures) greater than the 10^{-4} risk level are generally not allowed by federal and state regulatory agencies.

3.2. The US EPA's Guidance *for Conducting Remedial Investigations and Feasibility Studies Under CERCLA, Interim Final* (October 1988), has as a step in the evaluation process, a determination as to "[w]hether the remediation goals for all carcinogens of concern . . . provides protection within the risk range of 10^{-4} to 10^{-7}." (page 4-15). The lower end of this range is a lifetime cancer risk of one excess case of cancer per 10,000,000 people.

In *Risk Assessment Guidance for Superfund: Volume I—Human Health Evaluation Manual (Part B, Development of Risk-based Preliminary Remediation Goals), Interim* (December 1991), the US EPA states that "action is generally warranted at a site when the cumulative carcinogenic risk is greater than 10^{-4}. . . ," and that preliminary remediation goals are "not needed for any chemicals in a medium with a cumulative cancer risk of less than 10^{-6}." When the cancer risk for a medium is "within the range of 10^{-6} to 10^{-4}, a decision about whether or not to take action is a site-specific determination." (page 15).

3.3. The DOD's Base Realignment and Closure (BRAC) Cleanup Plan Guidebook (Fall, 1993) identifies "areas of contamination below action levels" for carcinogens (page 4-52) as areas that "risk estimates completed for contamination do not do the following:"

- Exceed 10^{-6} for any carcinogenic hazardous substance or petroleum constituent detected in any medium.
- Exceed 10^{-6} for all carcinogenic hazardous substances and petroleum constituents, taken together, in any exposure pathway.
- Exceed 10^{-4} for all carcinogenic hazardous substances and petroleum constituents accumulated across all pathways.

3.3.1. The DOD BRAC Cleanup Plan Guidebook states: "At present, sites exhibiting a cancer risk of 10^{-4} or greater are considered unacceptable, and require action to protect human health. Sites with cancer risks below 10^{-6} are considered acceptable, and are likely candidates for NFA [no further action]. Sites exhibiting risks between these two values require the exercise of considerable professional judgment on a site-by-site basis. . . . The classification of the carcinogens, and the likelihood of the exposure assumptions and the future land use scenarios should be considered in site-specific interpretations of the risk estimate. The result will facilitate the identification of site-specific solutions and actions that are appropriate for each site to protect human health and the environment. However, consistency across a given installation is desirable and a general consistent installation-wide approach to cost/benefit analysis of remedial alternatives will facilitate application of risk management policies." (page 4-71).

3.3.2. The DOD continues: "Examples [of sites that require special consideration] are sites . . . where a proven human (class A) carcinogen is present, resulting in lower acceptable risk estimates." (page 4-71).

3.3.2.1. The US EPA has designated all radionuclides to be Class A carcinogens, "based on their property of emitting ionizing radiation and on the extensive weight of epidemiological evidence of radiation-induced cancer in humans." (US EPA, *Risk Assessment Guidance for*

Superfund: Volume I—Human Health Evaluation Manual (Part B, Development of Risk-based Preliminary Remediation Goals), Interim, December 1991, page 33.)

4. RADIATION EXPOSURES—CANCER RISK AND EXPOSURE LIMITS

4.1. Radiation standards are established or recommended by a number of agencies, including the US EPA, the NRC, the National Academy of Sciences/National Research Council (NAS/NRC), the National Council for Radiation Protection and Measurements (NCRP), the International Council for Radiological Protection (ICRP), and the California Department of Health Services (DHS). These groups utilize a linear dose/effect relationship for the estimate of radiation effects, extrapolating to low exposures from the high exposures that are associated with human radiogenic cancer.

4.1.1. Lifetime cancer risk from radiation exposure is estimated in the NAS/NRC's *Health Effects of Exposure to Low Levels of Ionizing Radiation,* BEIR V (Table 4.4, Page 176, NAS/NRC, 1990) to be 520 and 600 excess cancer deaths per 100,000 for males and females, respectively, for a continuous exposure of 1 milligray per year (100 millirads per year). From these values, an estimated lifetime risk of 6×10^{-5} per mrad/yr results. Hence, 0.016 mrad/yr would yield a lifetime cancer risk of 1×10^{-6}, and 1.6 mrad/yr would yield a lifetime cancer risk of 1×10^{-4}.

4.1.2. The NRC, in its 1990 Below Regulatory Concern Policy Statement, based on reports by the United Nations Scientific Committee on the Effects of Atomic Radiation and ICRP, cited an annual cancer risk of 5×10^{-7} per mrem/yr, or a lifetime (70-yr) risk of 3.5×10^{-5}. From this risk, an exposure of 0.028 mrem/yr would result in a lifetime cancer risk of 1×10^{-6}, and 2.8 mrem/yr would result in a lifetime cancer risk of 1×10^{-4}. The estimates of cancer risk per exposure are helpful for purposes of this guidance. In 1993, NRC abandoned its Below Regulatory Concern Policy Statements.

4.1.3. The NCRP, in *Limitation of Exposure to Ionizing Radiation,* (Table 7.1, Report No. 116, 1993) presents estimates of 5×10^{-2} excess fatal cancers per sievert (100 rem) and 1×10^{-2} excess non-fatal cancers per sievert, based on NCRP and ICRP reports. These can be summed to equal 6×10^{-2} per sievert, or 6×10^{-2} per 100 rem, or, with a linear assumption, 6×10^{-7} per mrem. From this, an annual exposure of 1 mrem each year for 70 yr would result in a lifetime risk of 4.2×10^{-5} excess cases of cancer. From this, an annual exposure of 0.024 mrem would result in a lifetime cancer risk of 1×10^{-6}, and 2.4 mrem would result in a lifetime cancer risk of 1×10^{-4}.

4.2. Based upon the doses and risk estimates presented above, lifetime cancer risks can be approximated for various lifetime annual radiation exposures, as presented in Table 4-1.

4.2.1. The current radiation standard for workers is 5,000 mrem/yr .

4.2.2. Current federal and state standards for members of the general public include 100 mrem/yr for members from all radiation sources, 25 mrem/yr from nuclear power operations or radioactive waste, 10 mrem/yr from airborne radionuclide emissions, 4 mrem/yr from radionuclides in drinking water.

Table 4-1. Lifetime (70-year) cancer risks and corresponding annual radiation exposures. For purposes of conversion among risk levels, the exposure/risk relationship is assumed to be linear.

Lifetime cancer risk	Annual radiation exposure (mrem/yr)
10^{-2}	200
10^{-3}	20
10^{-4}	2
10^{-5}	0.2
10^{-6}	0.02

4.2.2.1. Current standards are for federal operations (*i.e.*, Department of Energy facilities), or for permitted operations that are regulated by federal or state agencies (*i.e.*, US NRC, US EPA, or the California DHS).

4.2.2.1.1. As described by the NRC in 1992, its criteria for acceptable levels of radioactive contamination associated with cleanup are inconsistent and not binding on NRC licensees.

4.4.2.2. Standards related to the cleanup of radioactive contamination and restoration of sites are under development by the US NRC and the US EPA. The NRC's proposed regulations are to be available in spring of 1994, and EPA's, later in 1994.

4.4.2.3. Existing California law (California Health and Safety Code §25249.5, *et seq.*) requires warnings for exposure to radionuclides and may limit discharges of radioactivity to sources of drinking water if lifetime cancer risks exceed 10^{-5}.

5. BENEFITS OF A COMMON APPROACH TO REGULATING ENVIRONMENTAL CARCINOGENICITY

5.1. A uniform, risk-based approach to dealing with radioactive materials and with chemical carcinogens would enable regulators and the public to ensure that environmental cleanup is targeting the exposures that pose the greatest carcinogenic risk.

5.2. A uniform approach would enable radioactive materials on closing military bases to be addressed in the same manner as chemical carcinogens (see Section 3.2, above).

5.2.1. Such an approach allows comparisons of sites based on cancer risk, no matter whether concerns are radiation-related, chemical-related, or both.

5.2.2. Such an approach provides a basis prioritization of sites based on cancer risk, for purposes of resource utilization.

5.2.3. Such an approach provides for consistency in dealing with carcinogenic substances, since the focus is on the risk, and not the source of the risk (e.g., radiation vs. chemical).

5.2.4. In determining the overall health risk to the public from environmental exposures, the total cancer risk from radioactive and non-radioactive materials should be considered in the evaluative process.

5.3. Currently, the regulation of radiation exposures to minimize cancer risk, when compared with the regulation of exposures to carcinogenic chemical contaminants and expressed in terms of permitted lifetime risk, is generally less restrictive (see Table 5-1).

5.4. The establishment of standards to limit radiation exposures to the same cancer risk level used in the regulation of chemical exposures would require that the standards be between 0.02 millirem per year and 2 millirems per year.

5.4.1. These limits would be applied to environmental contamination that results in radioactivity ingested or inhaled by a person and from external irradiation from that contamination (*e.g.*, air, water, and ingested soil, and external exposures from contaminated soil).

5.4.2. Exposures would be in excess of background levels of radioactivity in water, soil, and air, as discussed in below.

Table 5-1. Comparison of lifetime cancer risks and annual radiation exposures, with notes on selected standards.[1]

Chemical standard	LIFETIME CANCER RISK or ANNUAL RADIATION EXPOSURE	Radiation standard
	10,000 mrem/yr	
	10^{-1}	Workplace limit (5,000 mrem/yr)
Cancer risk at occupational limit—vinyl bromide	**1,000 mrem/yr**	
Cancer risk at occupational limit—p-toluidine	**10^{-2}**	
	100 mrem/yr	NRC/DOE limit—all sources (100 mrem/yr)
Cancer risk at occupational limit for several chemicals (acrylamide, amitrole, carbon tetrachloride, chloroform, o-toluidine)	**10^{-3}**	EPA action level for radon in indoor air (4 pCi/l) EPA limit—Nuclear Power Operations (25 mrem/ NRC limit—Radioactive Waste (25 mrem/yr)
	10 mrem/yr	EPA limit—Air (10 mrem/yr) EPA limit—Drinking Water (4 mrem/yr)
Upper limit—public (non-occupational) exposures to chemical carcinogens (e.g. trihalomethanes as byproducts of drinking water disinfection)	**10^{-4}**	
	1 mrem/yr	NCRP Negligible individual dose (1 mrem/yr)
California Proposition 65 standard[2]; Air "Toxic Hot Spots" notification requirement	**10^{-5}**	
	0.1 mrem/yr	
"De minimis" level for exposures to chemical carcinogens--usually not regulated below this level (e.g., California Recommended Public Health Levels for drinking water)	**10^{-6}**	
	0.01 mrem/yr	
	10^{-7}	

[1]Lifetime cancer risk for radiation exposures is estimated to be 4.2×10^{-5} excess cases of cancer for an annual exposure of 1 mrem each year for 70 years. For chemical carcinogens, cancer risk is estimated by methods utilized by the US EPA and other federal regulatory agencies, and by State of California regulatory agencies. The methods are generally consistent, though for certain chemicals, the specific risk may differ among different federal and state agencies. Radiation standards from US EPA, *Issues Paper on Radiation Site Cleanup Regulations*, EPA 402-R-93-084, September 1993. Cancer risks from occupational exposures are taken from the US Occupational Safety and Health Administration's Final Rule on Air Contaminants 29 CFR Part 1910, Section 15, "Substances for which limits are based on avoidance of cancer," *Federal Register* 54: 2668 (1989).

[2]Includes radionuclides.

6. BACKGROUND RADIATION CONSIDERATIONS

6.1. Radiation from natural sources in the environment results in external and internal radiation exposures to people. This is usually around 300 mrem/yr. Long-lived fission products deposited as world-wide fallout from historic above-ground testing of nuclear weapons also contribute to the global environmental radioactivity burden and to ambient background radiation.

6.2. Recommended cleanup levels are exclusive of location-specific ambient background radioactivity. For purposes of this document, "ambient" includes radioactivity from global fallout associated with above-ground nuclear weapons testing, and radioactivity from natural origins within (1) building materials such as bricks and aggregate, and (2) fertilizers.

6.3. Resulting cancer risks are those that result from radiation exposures in excess of background exposures.

6.4. Cleanup of a particular radionuclide need not be to levels below its background concentration for a given site or medium.

6.5. Determination of background radiation levels is an important part of the site characterization process, when embarking on a cleanup of a radionuclide contaminated site.

7. DETERMINATION OF RADIONUCLIDE CONCENTRATION LIMITS AND EXTERNAL RADIATION EXPOSURES

7.1. The following default assumptions should be used in determining exposures to radionuclide contaminated soil, water, or air, unless scientifically more appropriate values can be justified:

7.1.1. Drinking water consumption: 2 liters per day.

7.1.2. Air inhalation: 20 cubic meters per day.

7.1.3. Soil ingestion: 0.1 gram per day.

7.1.4. Lifespan: 70 years (25,500 days).

7.1.5. Residence time on soil: 70 years.

7.2. In determining radiation exposures, the dosimetric monitoring, documentation and calculations should be clearly shown and references should be appropriately identified. Any method or methods that are utilized in the determination of radiation exposure and dose calculation should follow the hierarchy of methods set forth in Section 8.

7.3. Dose calculations and risk should be based on the tissue or organ of concern—that is, the tissue or organ that received the greatest committed dose equivalent per unit of radioactivity intake. Where there is no specific target tissue or organ, the total body should be the tissue or organ of concern, and the total effective dose equivalent should be used.

8. METHODS OF ANALYSIS FOR RADIONUCLIDES IN ENVIRONMENTAL MEDIA AND EXTERNAL RADIATION EXPOSURES

8.1. "Method of analysis" or "methods of analysis" refer to the method or methods of detection of radiation exposure or detection and calculation of radiation exposure or of a radionuclide in a particular environmental medium, including but not limited to, water, air, soil, or food.

8.1.1. Included herein are methods and procedures concerning the number of samples and the frequency and site of sampling that are appropriate for the monitoring of radioactivity in environmental media or external radiation exposures.

8.1.2. The calculations of dose, dose equivalence, or other expressions of absorption of deposited energy associated with the interaction of ionizing radiation with biological cells, tissues, organs, etc., are also considered to be within the realm of 'method of analysis."

8.2. In performing an analysis to determine external radiation exposures of a contaminated site, or background external radiation exposures, generally accepted standards and practice, including, but not limited to, radiation monitoring, location and frequency of sampling, equipment, collection of data, statistical analysis, interpretation of results, modeling and dose calculations should be observed.

8.3 In performing an analysis to determine the concentration of a given radionuclide in a given environmental medium, or the background concentration of that radionuclide in that medium, generally accepted standards and practice, including, but not limited to, location and frequency of sampling, sample collection, numbers of samples , sample storage, and preparation, radiochemical analysis, statistical analysis, interpretation of results, modeling and dose calculations should be observed.

8.4. Complete written documentation should be maintained for all procedures, including but not limited to, frequency and location of sampling, types of dosimeters and instrumentation used, sample collection, sample handling and chain of custody, storage, and preparation, analyses, and dose calculations.

8.5. The following is the hierarchy that is to be utilized in establishing the method or methods of analysis to be used for the evaluation of environmental radioactivity, for purposes of describing radioactive contamination and for establishing background radiation levels.

8.5.1. If the California DHS has adopted or employs a method of analysis for external radiation exposures or for a radionuclide in a specific medium, that method is the appropriate method of analysis. If more than one method of analysis has been adopted or is employed by DHS, each may be used as a method of analysis.

8.5.1.1 The DHS's Radiologic Health Branch's Policy Memorandum "Clearance Inspection and Survey", Policy No. IPM-88-2, effective September 15, 1991, identifies the procedure to verify that a facility in which licensed materials were used has been decontaminated to acceptable levels and to assure that the facility will not present a radiation hazard to future occupants.

8.5.2. If DHS has not adopted or does not employ a method of analysis, a method of analysis for external radiation exposures or for a radionuclide in a specific medium adopted or employed by another state or local agency (*e.g.*, the Department of Toxic Substances Control, the Air Resources Board, a local air pollution control district, the State Water Resources Control Board or a Regional Water Quality Control Board) is the appropriate method of analysis. If more than one method of analysis has been adopted or is employed by another state or local agency, each may be used as a method of analysis.

8.5.3. If no state or local agency has adopted or employs a method of analysis, a method of analysis for external radiation exposures or for a radionuclide in a specific medium adopted or employed by a federal regulatory agency (*e.g.*, the US EPA, or the US NRC) is the appropriate method of analysis. If more than one method of analysis has been adopted or is employed by a federal regulatory agency, each may be utilized as a method of analysis.

8.5.3.1. The DOD BRAC Cleanup Guide (page 4-55) directs BRAC Cleanup Teams to review data in accordance with the outline given in section 5 of the US EPA guidance document *Guidance for Data Usability in Risk Assessment.*

8.5.3.2. The document *Residual Radioactive Contamination from Decommissioning, Technical Basis for Translating Contamination Levels to Annual Total Effective Dose Equivalent, Final Report,* by W. E. Kennedy, Jr., and D. L. Strange, NUREG/CR-5512, PNL-7994, Vol. 1, October 1992 (reprinted January 1993), provides generic and site-specific estimates of radiation dose for exposures to residual radioactivity after facilities decommissioning. It was prepared for the NRC's Office of Regulatory Applications.

8.5.4. If no regulatory agency has adopted or employs a method of analysis, a method of analysis for external radiation exposures or for a radionuclide in a specific medium that is generally accepted by the scientific community—as evidenced by its publication in compilations by professional and scientific associations or societies, in peer-reviewed technical journals published by such associations or societies, or in technical documents prepared for government regulatory agencies—is the appropriate method of analysis. If more than one method of analysis has been generally accepted by the scientific community, each may be utilized as a method of analysis.

9. USE OF DRINKING WATER STANDARDS AS LIMITS OF RADIATION EXPOSURE

9.1. Whenever a source of drinking water is contaminated with a radionuclide, cleanup of an area should be to a concentration resulting in a cancer risk level lower than 10^{-6} to 10^{-4}, except as noted below.

9.1.1. Whenever a source of drinking water is contaminated with a radionuclide for which a specific drinking water maximum contaminant level (MCL) exists, cleanup need not be more restrictive than the MCL for that radionuclide for purposes of protecting public health.

9.1.1.1. California drinking water MCLs exist for the following radionuclides:

- Hydrogen-3 (The California MCL is 20,000 pCi/l)
- Strontium-90 (8 pCi/l)
- Radium-226 and radium-228, combined (5 pCi/l)
- Natural uranium (20 pCi/l—based on chemical toxicity)

9.1.2. Discharges or releases of radioactivity into sources of drinking water may be subject to other regulation and enforcement and should be limited accordingly.

10. USE OF CURRENT ACTION LEVEL FOR RADON IN INDOOR AIR

10.1 The action level of 4 picocuries of radon per liter of air applies to residential indoor air, consistent with State and federal law.

11. USE OF FEDERAL STANDARDS FOR RADIUM IN SOILS

11.1 The Uranium Mill Tailings Radiation Control Act (UMTRCA) and regulations in 40 CFR 192 provide guidance for the cleanup of Department of Energy uranium mill tailing sites for unrestricted use. They state that a site must achieve a concentration of less than 5 pCi of radium per gram above the typical background level for the top 15 centimeters of soil. At depths greater than 15 cm, however, the maximum concentration of radium can be up to 15 pCi/g.

11.1.1. These standards are appropriate for use in situations involving radium contaminated soils, in the absence of other federal guidance. However, they do not apply to soil contaminated by spills or disposal of radium paint, or to radium-containing dials, knobs and gauges that are present in soil.

11.2 Section 11.1 notwithstanding, the NRC and EPA are developing guidance documents for the cleanup of residual radioactivity for property intended for unrestricted use.

12. HEALTH RISKS FROM URANIUM

12.1 In evaluating the human health concerns from uranium exposures, the risks associated with uranium's chemical toxicity (principally to the kidneys) may exceed the risks related to its radioactivity. Hence, each endpoint should be evaluated as cleanup options are being considered.

13. CALCULATIONS OF RADIATION EXPOSURES THAT RESULT FROM SELECTED RADIONUCLIDES IN WATER, AIR AND INGESTED SOIL

13.1. Comparison of concentrations of selected radionuclides in water, air and soil with various cancer risk levels (10^{-6}, 10^{-5}, or 10^{-4} lifetime cancer risk).

13.1.1. Table 13-1.1 presents various intake levels of selected radionuclides and the corresponding lifetime cancer risk from ingested contaminated water. Intakes from water to yield the various lifetime cancer risks are calculated from US EPA's Health Effects Assessment Summary (January 1992). The risk per pCi from US EPA is converted to pCi ingested for a specific cancer risk, divided by (365 days/yr x 70 yr =) 25,550 days, for a daily intake. This value is divided by 2 liters per day to yield corresponding radionuclide concentrations in ingested water.

Table 13-1.1. Concentrations of specific radionuclides in drinking water that would yield various lifetime cancer risks. The drinking water consumption rate is two liters per day for 70 years.

Radionuclide	Lifetime Cancer Risk:	10^{-6} (pCi/l)	10^{-5} (pCi/l)	10^{-4} (pCi/l)
Hydrogen-3		370	3,700	37,000
Carbon-14		22	220	2,200
Cobalt-60		1.3	13	130
Strontium-90		6	60	600
Iodine-131		0.55	5.5	55
Cesium-137		0.7	7	70
Radium-226		0.16	1.6	16
Uranium-238		1.3	13	130
Plutonium-239		0.085	0.85	8.5

13.1.2. Table 13-1.2 presents various intake levels of selected radionuclides and the corresponding lifetime cancer risk from inhaling contaminated air. Intakes from air to yield the various lifetime cancer risks are calculated from US EPA's Health Effects Assessment Summary (January 1992). The risk per pCi from US EPA is converted to pCi inhaled for a specific cancer risk, divided by (365 days/yr x 70 yr =) 25,550 days, for a daily intake. This value is divided by 20 cubic meters per day to yield corresponding radionuclide concentrations in inhaled air.

Table 13-1.2. Concentrations of specific radionuclides in air that would yield various lifetime cancer risks. The inhalation rate is 20 cubic meters of air per day for 70 years.

Lifetime Cancer Risk:	10^{-6}	10^{-5}	10^{-4}
Radionuclide	(pCi/m^3)	(pCi/m^3)	(pCi/m^3)
Hydrogen-3	26	260	2,600
Carbon-14	320	3,200	32,000
Cobalt-60	0.01	0.1	1
Strontium-90	0.04	0.4	4
Iodine-131	0.08	0.8	8
Cesium-137	0.11	1.1	11
Radium-226	0.00065	0.0065	0.065
Uranium-238	0.00008	0.0008	0.008
Plutonium-239	0.00005	0.0005	0.005

13.1.3. Table 13-1.3 presents various intake levels of selected radionuclides and the corresponding lifetime cancer risk from ingested soil. Intakes from soil to yield the various lifetime cancer risks are calculated from US EPA's Health Effects Assessment Summary (January 1992). The risk per pCi from US EPA is converted to pCi ingested for a specific cancer risk, divided by (365 days/yr x 70 yr =) 25,550 days, for a daily intake. This value is divided by 0.1 gram per day, to yield corresponding radionuclide concentrations in ingested soil.

Table 13-1.3. Concentrations of specific radionuclides in ingested soil that would yield various lifetime cancer risks. The ingestion rate is 0.1 gram of soil ingested per day for 70 years.

Radionuclide	Lifetime Cancer Risk: 10^{-6} (pCi/g of soil)	10^{-5} (pCi/g of soil)	10^{-4} (pCi/g of soil)
Hydrogen-3	7,400	74,000	740,000
Carbon-14	430	4,300	43,000
Cobalt-60	26	260	2,600
Strontium-90	120	1,200	12,000
Iodine-131	11	110	1,100
Cesium-137	14	140	1,400
Radium-226	3.2	32	320
Radium-228	3.9	39	390
Uranium-238	25	250	2,500
Plutonium-239	0.17	1.7	17

14. CALCULATIONS OF EXTERNAL RADIATION EXPOSURES RESULTING FROM RADIONUCLIDES IN SOIL

14.1. Radionuclides in soil, besides presenting an opportunity for human exposure via the pathway of soil ingestion, can also result in human exposures from external radiation, owing to emissions related to their radiologic decay. Table 14-1 presents various concentrations of selected radionuclides and the corresponding lifetime cancer risk from external exposures (10^{-6}, 10^{-5}, or 10^{-4} lifetime cancer risk).

Table 14-1. Lifetime cancer risks from external exposures to radionuclides in soil. Lifetime cancer risks from radionuclides in soil are calculated from US EPA's Health Effects Assessment Summary (January 1992). The annual risk per pCi/g from US EPA is converted to lifetime risk by dividing the annual risk by 70 years.

Radionuclide	Lifetime Cancer Risk: 10^{-6} (pCi/g of soil)	10^{-5} (pCi/g of soil)	10^{-4} (pCi/g of soil)
Hydrogen-3	--	--	--
Carbon-14	--	--	--
Cobalt-60	0.002	0.02	0.2
Strontium-90	--	--	--
Iodine-131	0.01	0.1	1
Cesium-137*	0.007	0.07	0.7
Radium-226*	0.002	0.02	0.2
Radium-228*	0.005	0.05	0.5
Uranium-238*	0.4	4	40
Plutonium-239	840	8,400	84,000

*includes risks from radioactive decay chain products

15. SUMMARY

15.1. For closing military bases, the following should occur:

15.1.1. A complete history of the use, storage, and disposal of radioactive material should be documented. Where information is lacking, the discussion should identify the extent in information gaps.

15.1.2. Known discrete radioactive items should be removed.

15.1.3. Diffuse radioactive contamination should be removed to a level that minimizes the risk of exposure to people.

15.2. Cleanup levels can rely upon appropriate existing standards for water, air, and soil.

15.2.1 Cleanup of radioactivity in water need not be more restrictive than drinking water MCLs for radionuclides.

15.2.2 Radon in indoor air need not be considered of concern at concentrations below the federal and state radon action levels of 4 pCi radon per liter of air.

15.2.3. In the absence of federal regulation, cleanup of radium in soil need not be more restrictive than 5 pCi/g for the top 15 cm of soil, consistent with EPA rules for cleanup of uranium mill tailings.

15.3. For areas that are intended to have unrestricted use upon release to the public, exposures from radionuclide contamination associated with radionuclides other than those identified in 15.2, should not result in a cancer risk in excess of 10^{-6} to 10^{-4}, and should be consistent with the cancer risks resulting from residual chemical carcinogens.

15.3.1. The corresponding limit on the cancer risk for areas that are intended to be unrestricted upon release to the public corresponds to the annual radiation exposures of from about 0.02 to 2 millirems per year.

15.3.2. The annual radiation exposure of from 0.02 to 2 millirems per year for areas that are intended to be unrestricted upon release to the public is in excess of background radiation exposures.

15.3.3. Pursuant to existing California law, exposures that result in cancer risks greater than 10^{-5} may require the property owner to provide warnings to the public.

15.4. The method or methods of analysis for external radiation exposures and for external ambient background radiation exposures should be scientifically appropriate, and consistent with existing regulations or guidelines.

15.5. The method or methods of analysis for a radionuclide in a specific medium and for the ambient background concentration of a radionuclide in that medium should be scientifically appropriate, and consistent with existing regulations or guidelines.

15.6. For exposures from radionuclide contamination associated with radionuclides other than those identified in 15.2, the following applies: If the 10^{-6} to 10^{-4} cancer risk limit corresponds to a radiation exposure that is below background radiation exposures, cleanup should be to the level of non-detection (*i.e.*, to background levels).

15.6.1. If the cancer risk limit corresponds to a radiation exposure that is below background radiation exposures, then an external radiation exposure from radioactive contamination that is greater than background, using appropriate radiation monitoring and statistical methodologies, exceeds the limit. This finding should prompt further cleanup and reevaluation of whether the property is to be released for unrestricted use.

15.6.2. If the cancer risk limit corresponds to a concentration of radionuclide contamination in a given medium that is below the background concentration of that radionuclide in that medium, then a concentration of the radionuclide in a medium that is greater than its background concentration in that medium, using the appropriate method of analysis including appropriate statistical methods, exceeds the limit. This finding should prompt further cleanup and reevaluation of whether the property is to be released for unrestricted use.

16. REFERENCES

California Code of Regulations Title 22 Chapter 3. Safe Drinking Water and Toxic Enforcement Act of 1986, §12000 *et seq.* List of substances subject to the Act and implementing regulations.

California Department of Health Services, Radiologic Health Branch, Policy Memorandum "Clearance Inspection and Survey", Policy No. IPM-88-2, effective September 15, 1991.

California Health and Safety Code §25249.5, *et seq.*, the Safe Drinking and Toxic Enforcement Act of 1986 ("Proposition 65").

California Health and Safety Code §44300, *et seq.*, Air Toxics "Hot Spots" Information and Assessment Act of 1987.

Department of the Army, Corps of Engineers, Memorandum to Regional Commands Re: Awareness of Radioactive Materials Used at Department of Defense Facilities, December 8, 1993.

Department of Defense, Base Realignment and Closure (BRAC) Cleanup Plan (BCP) Guidebook, Fall 1993.

National Academy of Sciences/National Research Council, *Health Effects of Exposure to Low Levels of Ionizing Radiation*, BEIR V, NAS/NRC, 1990.

National Council on Radiation Protection and Measurements, *Limitation of Exposure to Ionizing Radiation*, NCRP Report No. 116, NCRP, 1993.

US Environmental Protection Agency, *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA, Interim Final* , EPA 540-G-80-804, October 1988.

US Environmental Protection Agency, *Risk Assessment Guidance for Superfund: Volume I—Human Health Evaluation Manual (Part B, Development of Risk-based Preliminary Remediation Goals) , Interim,* (December 1991), EPA/540/R-52/003, December 1991.

US Environmental Protection Agency, Health Effects Assessment Summary, Table 4A, Radionuclide Carcinogenicity—Slope Factors (in Units of Picocuries), January 1992.

US Environmental Protection Agency, *Issues Paper on Radiation Site Cleanup Regulations,* EPA 402- -93-084, September 1993.

US Occupational Safety and Health Administration, Final Rule on Air Contaminants, 29 CFR Part 1910, Section 15, "Substances for which limits are based on avoidance of cancer," *Federal Register* 54: 2668, 1989.

US Nuclear Regulatory Commission, Below Regulatory Concern Policy Statement, 1990 (Withdrawn by NRC in 1993).

US Nuclear Regulatory Commission, A Summary of NRC's Interim Radiological Cleanup Criteria and Current Dose Bases, Decommissioning and Regulatory Issues Branch, November, 1992.

US Nuclear Regulatory Commission, *Residual Radioactive Contamination from Decommissioning, Technical Basis for Translating Contamination Levels to Annual Total Effective Dose Equivalent, Final Report,* by W. E. Kennedy, Jr., and D. L. Strange, NUREG/CR-5512, PNL-7994, Vol. 1, October 1992 (reprinted January 1993).

California Department of Health Services

Base Cleanup Process for Environmental Radioactivity